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(54) **Method of forming buried oxide layers**

Verfahren zur Herstellung vergrabener Oxidschichten

Méthode pour former des couches enterrées d'oxide

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Description

[0001] The instant invention is directed to the manufacture of a silicon on insulator (SOI) wafer, and more particularly to a method of producing an SOI wafer having a buried oxide layer at a lower cost and which is also more reliable than conventionally known wafers. According to the method of the invention, such an SOI wafer can be produced using standard equipment in a normal production facility.

[0002] SOI wafers having buried oxide layers are an attractive technology for deep-submicrometer CMOS and radiation-hardened devices because the buried oxide layer offers both device isolation and the ability to getter defects, such as oxygen and metallic ions, away from the operating region of the device.

[0003] There are generally two conventional methods for producing SOI wafers. The first is SIBOND. With SIBOND wafers, as illustrated in Figure 1A, an oxide layer 12 is formed on the surface of a substrate 10. A second silicon wafer 14 is bonded to the top surface of the oxide layer 12. Using this method, the top wafer 14 must be formed relatively thin so that the oxide layer 12 is at the desired depth to achieve the device isolation. This results, in an increased potential for defects as the thin layer is worked. Another drawback to the SIBOND wafer is manufacturing cost. Moreover, due to the complexity of the manufacturing process, the SOI wafer cannot be incorporated into the "in-house" production of a semiconductor device. Instead, the SOI wafer must be purchased from an outside source.

[0004] The second method employed to produce SOI wafers is SIMOX (i.e., Separation by Implanted Oxygen). In SIMOX technology, as illustrate in Figure 1B, oxygen 16 is implanted into the substrate 10 at relatively low energies to form the buried oxide layer 13. As with SIBOND, one drawback for a semiconductor device manufacturer who wishes to use conventional SIMOX wafers is that the equipment needed to produce such wafers is not of the type normally used in manufacturing semiconductor devices. Thus, typically SIMOX wafers must also be purchased from an outside source. Accordingly the costs of using SOI wafers is increased.

[0005] Another drawback associated with SIMOX wafers arises from the Oxygen implantation process itself. The oxygen implantation is carried out at relatively low energy levels, which tends to form defect regions in the surface of the wafer down to the buried oxide layer 13 through portion 15 of the substrate 10. Moreover, SIMOX wafers are typically considered "dirty", in the sense that significant amounts of iron impurities are introduced into the wafer during oxygen implantation. Since Oxygen is not a standard species for ion implantation, the implanting device must be configured in a way which introduces these unwanted impurities. One of the downsides of using SIMOX wafers is that the iron rich nature of the wafer will significantly hinder the production and/or operation of most semiconductor devices. Moreover, the oxygen implantation step is not practical for implementation in standard device production facilities as part of the manufacturing process.

[0006] DE-A-4110331 discloses a semiconductor wafer having a buried impurity layer formed by ion injection, the impurity layer being formed over a gettering layer so that, during annealing of the wafer, the crystal defects due to ion injection are absorbed into the gettering layer.

[0007] We shall describe a method of producing an SOI wafer which includes a buried oxide layer but which can be made using the type of equipment typically used by semiconductor manufacturers to reduce the costs associated with making and using SOI wafers.

[0008] We shall also describe a method for producing SOI or SOI like wafers which can be implemented in standard semiconductor device manufacturing processes. We shall further describe a method of producing an SOI wafer which is more reliable and does not have the undesirable impurities associated with the conventional SOI wafers.

[0009] It would also be an advantage if an SOI wafer could be produced in a standard production line without committing the entire production line to an SOI type wafer.

[0010] According to the present invention there is provided a method of selectively manufacturing wafers with and without a buried oxide layer at a desired depth, comprising the steps of providing a plurality of oxygen-rich wafers having a background oxygen level of approximately $1x10^{18}cm^{-3}$, implanting ions into each of the wafers to form a defect region at the desired depth in the wafer, the ions being implanted at an energy level at or above 1 MeV, and then annealing at least one of the wafers such that background oxygen in the wafer is gettered to the defect region to form a buried oxide layer, and subjecting at least one other of the wafers to a H_2 annealing treatment to prohibit the formation of a buried oxide layer.

[0011] In this manner the production of an SOI type substrate is selectively carried out and it is no longer necessary that an entire production line is committed to an SOI type wafer.

[0012] In one preferred embodiment of the invention phosphorus is used for the ion implantation at a dose of between $4.5x10^{14}/cm^2$ and $1x10^{15}/cm^2$.

[0013] In the accompanying drawings, by way of example only:

Figures 1A-1B illustrate a process used to manufacture an SOI wafer according to conventional techniques.

Figure 2 illustrates a device using SOI technology;

Figure 3A-3C illustrates a method of producing an SOI wafer according to an embodiment of the invention; and

Figures 4A-4D illustrate SIMS profiles of various wafers illustrating preferred features of the invention.

Detailed Description of the Preferred Embodiments

[0014] Figure 2 illustrates a device for which an SOI wafer manufactured according to the instant invention is to be used. In Figure 2, a substrate 20 includes a buried oxide layer 22. On the upper portion 24 of the wafer above the oxide layer 22, a semiconductor device 26 is formed. This type of structure is particularly advantageous in CMOS logic in that it prevents parasitic latch-up. This type of structure is also advantageous for use in radiation hardened devices, as it prevents problems associated with α-particles of radiation.

[0015] Figures 3A-3C illustrate a method for producing an SOI wafer according to an embodiment of the instant invention. In this embodiment, a standard P-type (100) wafer which is grown in an oxygen-rich environment and therefore has an oxygen-rich background level (*e.g.* approximately $1x10^{18}/cm^3$) is provided as shown in Figure 3A. As illustrated in Figure 3B, the oxygen-rich wafer is implanted with a standard species, in this case phosphorus (P), at an energy level of at least 1 MeV. While phosphorus is used in the example provided below, the instant invention is not limited to phosphorus. Any standard species which generates the desired defect region could be used. Typically, heavy ions (relative to phosphorus) such as arsenic can most easily be used to produce the desired effect. For lighter ions, such as boron, energy and dosage may need to be adjusted upward to account for lighter ion. It is also noted that the implantation step could be carried out through an oxide layer (not shown) on the surface of wafer 35. The dosage of the phosphorus implant can be varied according to the desired effect. In the specific examples provided below, the doses were varied between approximately $5x10^{14}/cm^2$ to $1x10^{15}/cm^2$.

[0016] The high energy phosphorus implantation of Figure 3B creates a zone of defects 31 as a function of the phosphorus implant. In the depicted example, the zone of defects 31 is approximately 1 micrometer beneath the surface of the wafer 35. Since the implantation energy is relatively high, the zone of defects 31 are formed as an amorphous layer roughly about 1 micrometer deep. The defect zone is not formed from the surface down to the region 31 (at 1 micrometer) as would be seen in conventional SIMOX oxygen implantation illustrated in Figure 1B. This is because a higher implantation energy is used as compared to the energy used for SIMOX oxygen implantation.

[0017] After the phosphorus implantation step is carried out, the wafer 35, including the zone of defects 31, is subjected to a 30-minute 960°C annealing process. As a result of the annealing process carried out in Figure 3C, the oxygen within the oxygen rich wafer 30 is drawn to the defects in the zone of defects 31. In other words, the background oxygen of the wafer 35 is drawn from both near the surface and from the bulk. Upon completion of the annealing process of Figure 3C, a zone of oxygen is collected where the defects 31 were formed. As a result, an SOI wafer including a buried oxide layer 32 at a depth of approximately 1 micrometer is formed. In this manner, during the annealing step, the oxygen is gettered to the defects created by the phosphorus implant in order to produce a buried oxide layer.

[0018] Figures 4A-4D illustrate SIMS profiles which illustrate features of the above described process for manufacturing an SOI wafer. Figure 4A shows a SIMS profile of the oxygen-rich wafer directly after a $1x10^{15}/cm^2$ phosphorus implant at 1 MeV was carried out in the manner illustrated in Figure 3B. The SIMS profile of Figure 4A illustrates the properties of a wafer before the annealing step illustrated in Figure 3C is carried out. As can be seen in Figure 4A, the background oxygen level 41 of the wafer is approximately $1x10^{18}$ atoms/cm^3. The location of the phosphorus implant 43 is also evident. Notably, Figure 4A also illustrates the absence of any buried oxygen layers within the wafer.

[0019] Figures 4B and 4C illustrate wafers manufactured according to the instant invention after the annealing step of Figure 3C is carried out on implants of phosphorus at dosages of approximately $5x10^{14}/cm^2$ and $1x10^{15}/cm^2$, respectively. As illustrated in Figure 4B at a dosage of $5x10^{14}$ cm^{-2} a distinct oxide layer is formed at the oxygen peak 42 approximately 1 micrometer deep. This layer is approximately 0.5 μm wide and has a peak level of $5x10^{18}cm^3$. As further illustrated by comparing Figure 4B with Figure 4A, the surrounding oxygen has been gettered in the production of the oxygen peak 42.

[0020] Figure 4C illustrates a SIMS profile of a wafer after the annealing step which was implanted with phosphorus at a level of approximately $1x10^{15}/cm^2$. As illustrated in Figure 4C this process produced two oxygen peaks 43 and 44 at approximately 0.3 and 1.0 μm, respectively. The first oxygen peak 44 is similar to the oxygen peak 42 in Figure 4B. The second peak 43 is produced as a result of the phosphorus implant at the higher dosage which knocks oxygen from the surface into the substrate. In other words, some of the oxygen at the surface is knocked into the substrate by the phosphorus. This effect is even more pronounced when the phosphorus implant is carried out through an oxide layer on the surface of the substrate. In this case, oxygen from the oxide layer is knocked deeper into the substrate to produce the second oxygen peak 43. Unlike the first oxygen peak, the second oxygen peak is not the result of defects created by the phosphorus implant, but rather is a result of oxygen actually moved from the surface to that region. This will be more fully understood from the description of the interferometry results described below.

[0021] In Figure 4D, a wafer is shown wherein phosphorus was implanted at a dose of $5x10^{14}/cm^2$ at approximately 1 MeV. In this case, prior to the annealing step illustrated in Figure 3C, the wafer is subjected to an H_2 15 minute 1,150°C annealing treatment. When the H_2 treatment is carried out prior to the annealing step illustrated in Figure 3C, significant oxygen layers are not formed within the wafer. A slight oxygen peak 48 can be seen. However, this oxygen peak is not at a significant level. Thus, the H_2 anneal can be used to essentially inhibit the formation of the oxide layer (i.e., when it is desired that the oxygen not be gettered to the defect zone, an H_2 treatment can be carried out in order to push the oxygen towards the bottom of the substrate).

[0022] In the above described manner, an H_2 anneal can be used along with the phosphorus implant in a standard production line. Thus, when it is desired to run the phosphorus implant, but not to create an SOI on some wafers, an H_2 treatment could be carried out prior to the annealing step. In other words, the production of an SOI type substrate could be selectively carried out. That is, the same implant could be carried out when it is desired to create the same junction, but if the buried O_2 layer was not desired, the hydrogen annealing step would be inserted between the steps illustrated in Figure 3B and Figures 3C. Thus, the instant method for producing an SOI wafer could be carried out in a production process as desired, without committing the entire production line to an SOI type wafer.

[0023] The wafers used to produce the SIMS profiles illustrated in Figures 4A-4D were subjected to an interferometric examination. The results provide a more complete explanation of the features of the instant invention. The results are illustrated in table 1 where the measured result indicates the presence of defects at a depth of approximately 1-micrometer.

TABLE 1

Wafer	Measured result at 1-Micrometer
Wafer 24 (Figure 4A)	None
Wafer 21 (Figure 4B)	≈1
Wafer 25 (Figure 4C)	≈1
Wafer 5 (Figure 4D)	≈1

[0024] As illustrated in the above table, the interferometric results demonstrate that in each of the instances except for wafer 24, a defect region is detected at the depth of approximately 1 micrometer. The results did not produce a defect region above the 1 micron region. It is noted that for wafer 24 while the defect region exists no oxide layer is formed at the 1 micron level in order to reflect and examine the defect region. While in wafer 5 (illustrated in Figure 4D) only a small oxygen peak is formed, it is sufficient to examine the defect region. Thus, according to these results it can be understood that according to the method of the instant invention, an oxide layer buried within the SOI wafer can be formed. The formation of the oxide layer can also be controlled by controlling the phosphorus implantation and/or the level of the background oxygen layer. Moreover, formation can be inhibited with an H_2 anneal.

Claims

1. A method of selectively manufacturing wafers with and without a buried oxide layer at a desired depth, comprising the steps of:

   providing a plurality of oxygen-rich wafers having a background oxygen level of approximately $1x10^{18}cm^{-3}$,
   implanting ions into each of the wafers to form a defect region at the desired depth in the -wafer, the ions being implanted at an energy level at or above 1 MeV, and then
   annealing at least one of the wafers such that background oxygen in the wafer is gettered to the defect region to form a buried oxide layer, and
   subjecting at least one other of the wafers to a H_2 annealing treatment to inhibit the formation of a buried oxide layer.

2. A method as claimed in claim 1, wherein the ions are phosphorus.

3. A method as claimed in claim 2, wherein the ions are implanted at a dose between $4.5x10^{14}/cm^2$ and $1x10^{15}/cm^2$.

4. A method as claimed in any one of the claims 1-3, further comprising the step of forming an oxide layer on a surface of each wafer prior to implanting the ions.

5. A method as claimed in any one of the preceding claims, wherein the annealing to form the buried oxide layer is carried out at approximately 960°C and for approximately 30 minutes.

6. A method according to any one of the claims 1-4 in which the H_2 annealing treatment is carried out at 1,150°c for 15 minutes.

Patentansprüche

1. Verfahren zum wahlweisen Herstellen von Wafern mit einer oder ohne eine vergrabene Oxidschicht an einer gewünschten Tiefe, mit den folgenden Schritten:

   Bereitstellen mehrerer sauerstoffreicher Wafer mit einem Hintergrund-Sauerstoffpegel von ungefähr $1x10^{18}$ cm^{-3},

   Implantieren von Ionen in jeden der Wafer zur Bildung eines defekten Bereiches in einer gewünschten Tiefe in dem Wafer, wobei die Ionen mit einem Energiepegel von 1 MeV oder höher implantiert werden, und anschließend

   Tempern mindestens eines der Wafer derart, dass der Hintergrund-Sauerstoff in dem Wafer auf den defekten Bereich gegettert wird, um eine vergrabene Oxid-Schicht zu bilden, und

   Durchführen einer H_2-Temperierungsbehandlung an mindestens einem anderen der Wafer zum Verhindern der Bildung einer vergrabenen Oxidschicht.

2. Verfahren nach Anspruch 1, bei dem die Ionen Phosphor-Ionen sind.

3. Verfahren nach Anspruch 2, bei dem die Ionen mit einer Dosis zwischen $4,5 \times 10^{14}/cm^2$ und $1 \times 10^{15}/cm^2$ implantiert werden.

4. Verfahren nach einem der Ansprüche 1-3, ferner mit dem Schritt des Bildens einer Oxidschicht auf einer Fläche jedes Wafers vor dem Implantieren der Ionen.

5. Verfahren nach einem der vorhergehenden Ansprüche, bei dem das Temperieren zur Bildung der vergrabenen Oxidschicht bei ungefähr 960°C und ungefähr 30 Minuten lang durchgeführt wird.

6. Verfahren nach einem der Ansprüche 1-4, bei dem die H_2-Temperierungsbehandlung bei 1150°C 15 Minuten lang durchgeführt wird.

Revendications

1. Méthode de fabrication de tranches avec et sans couche enterrée d'oxyde au choix à une profondeur désirée, comprenant les étapes de :

   fourniture d'une pluralité de tranches riches en oxygène ayant un niveau en oxygène à l'arrière-plan d'approximativement 1×10^{18} cm^{-3},
   implantation d'ions à l'intérieur de chacune des tranches de manière à former une région imparfaite à la profondeur désirée dans la tranche, les ions étant implantés à un niveau d'énergie égal ou supérieur à 1 MeV, puis recuit d'au moins une des tranches de telle manière que l'oxygène à l'arrière-plan dans la tranche est fixé par sorption dans la région imparfaite de manière à former une couche enterrée d'oxyde, et
   application au moins sur une autre des tranches d'un traitement de recuit de l'H_2 de manière à inhiber la formation d'une couche enterrée d'oxyde.

2. Méthode selon la revendication 1, dans laquelle les ions sont des ions de phosphore.

3. Méthode selon la revendication 2, dans laquelle les ions sont implantés à une dose comprise entre $4,5 \times 10^{14}$ $/cm^2$ et 1×10^{15} cm^2.

4. Méthode selon l'une quelconque des revendications 1 à 3, comprenant en outre l'étape de formation d'une couche d'oxyde sur une surface de chaque tranche préalablement à l'implantation des ions.

5. Méthode selon l'une quelconque des revendications précédentes, dans laquelle le recuit pour former la couche enterrée d'oxyde est exécuté à approximativement 960° C et pendant approximativement 30 minutes.

6. Méthode selon l'une quelconque des revendications 1 à 4, dans laquelle le traitement de recuit de l'H_2 est exécuté à 1 150° C pendant 15 minutes.

FIG. 1A

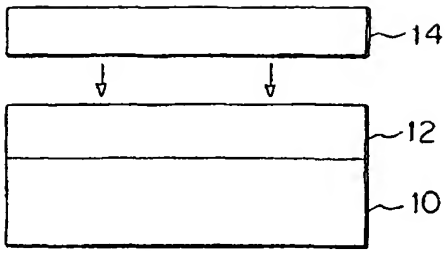
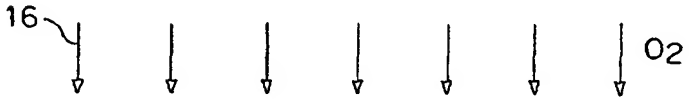


FIG. 1B



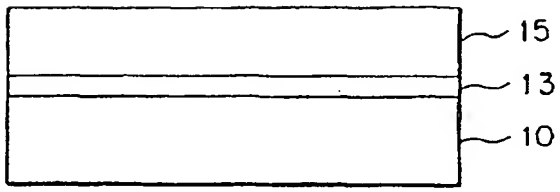


FIG. 2

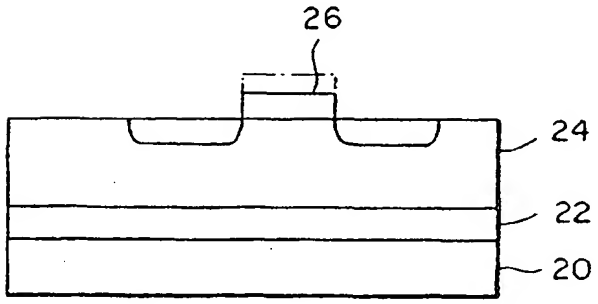


FIG.3A

FIG.3B

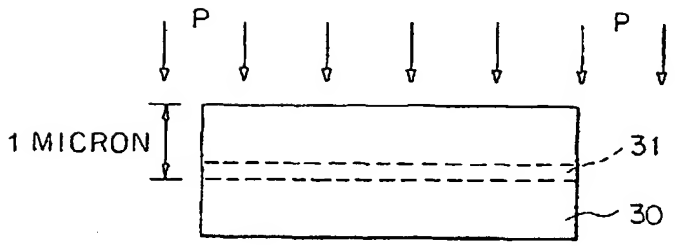


FIG.3C

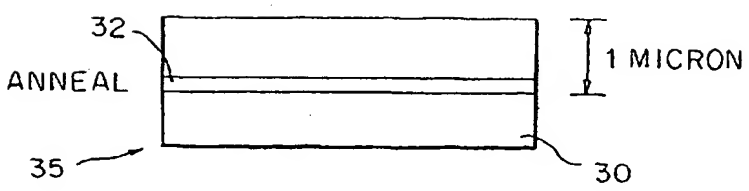


FIG. 4A

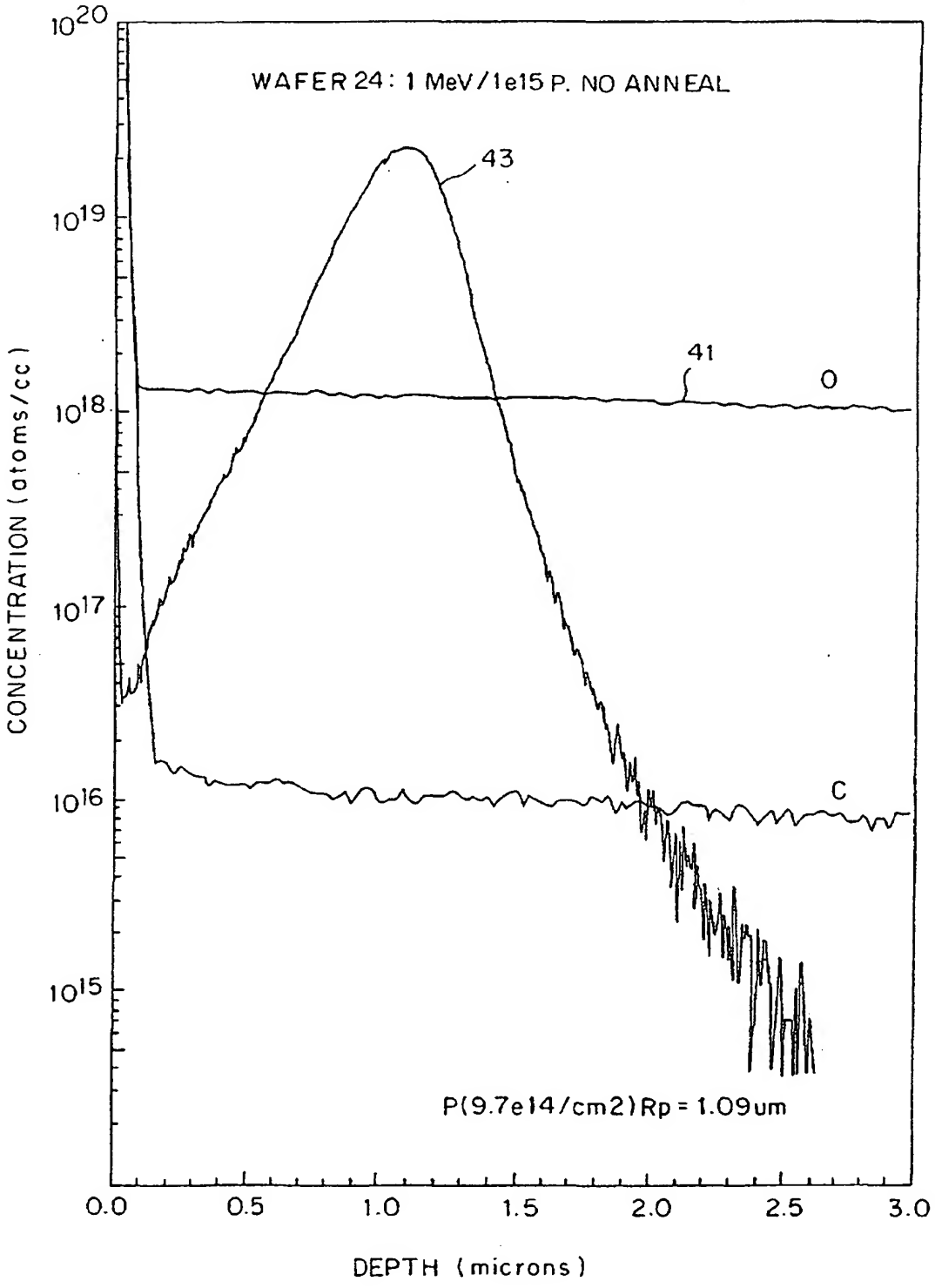

WAFER 24 : 1 MeV / 1e15 P. NO ANNEAL
43
41
O
C
P(9.7e14/cm2) Rp = 1.09um
CONCENTRATION (atoms/cc)
DEPTH (microns)
10^20
10^19
10^18
10^17
10^16
10^15
0.0
0.5
1.0
1.5
2.0
2.5
3.0

FIG. 4B

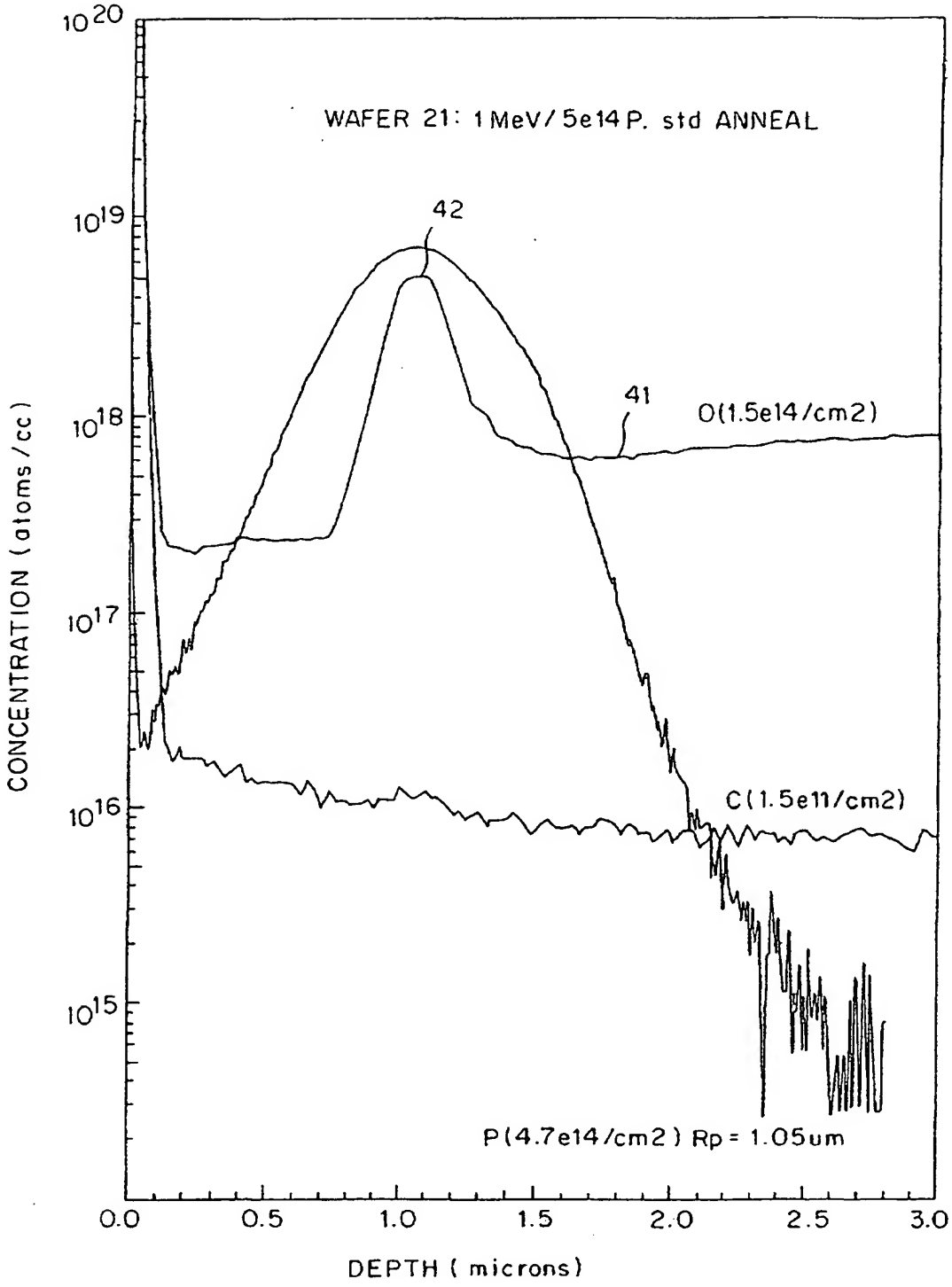

WAFER 21: 1MeV/5e14P. std ANNEAL
42
41
O(1.5e14/cm2)
C(1.5e11/cm2)
P(4.7e14/cm2) Rp = 1.05um
CONCENTRATION (atoms/cc)
DEPTH (microns)
10^20
10^19
10^18
10^17
10^16
10^15
0.0
0.5
1.0
1.5
2.0
2.5
3.0

FIG. 4C

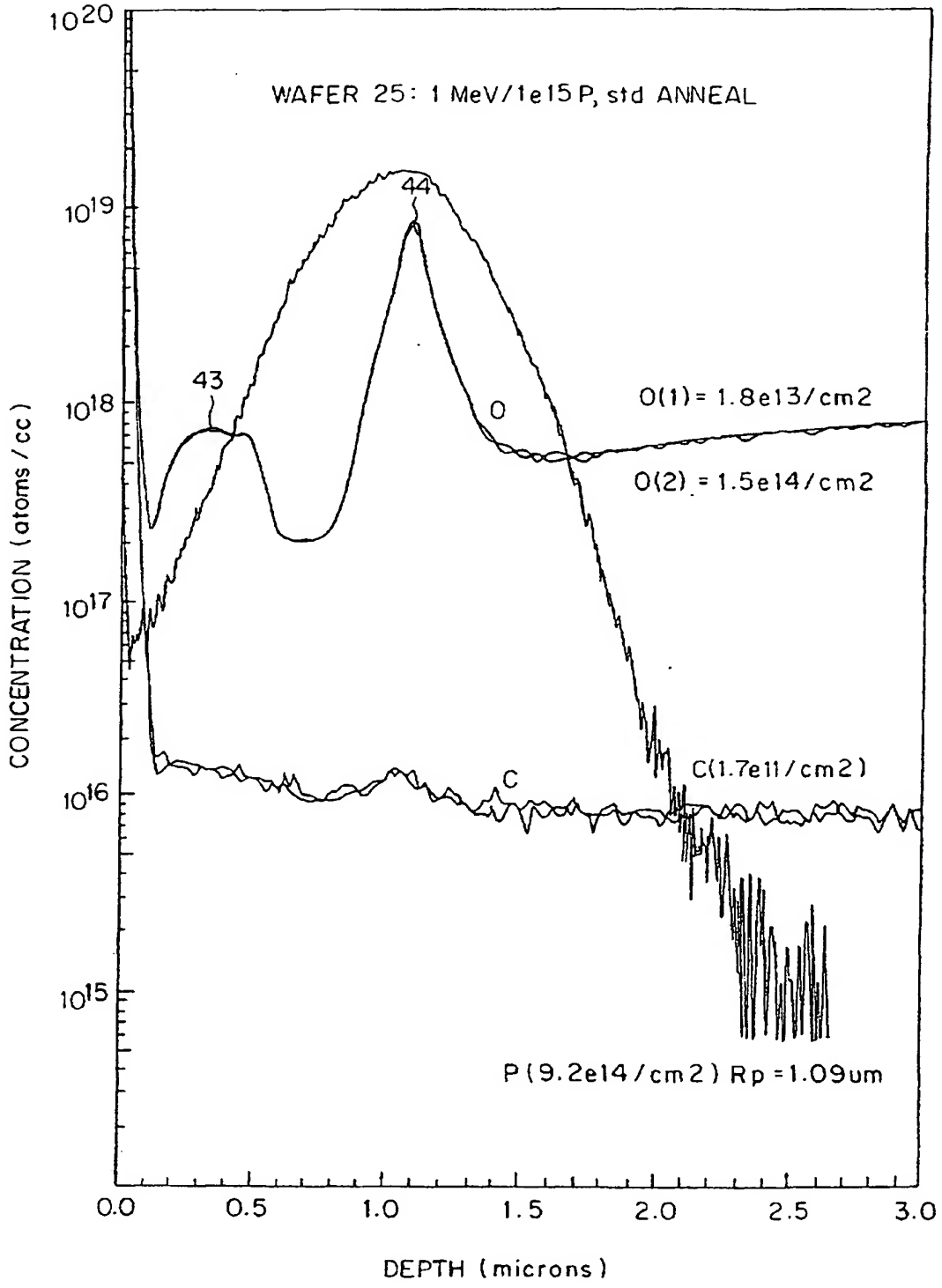
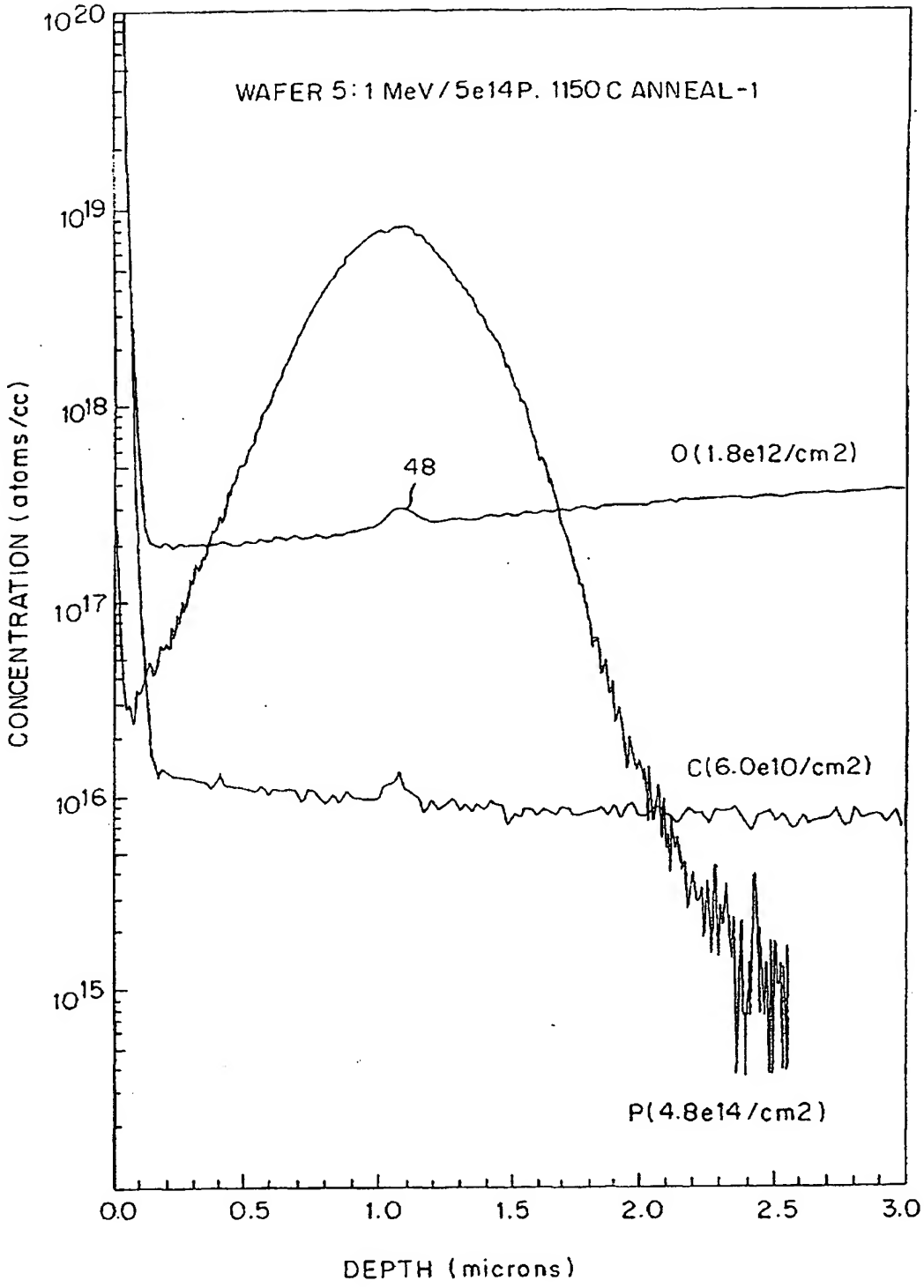

WAFER 25: 1 MeV/1e15 P, std ANNEAL
44
43
O
O(1) = 1.8e13/cm2
O(2) = 1.5e14/cm2
C
C(1.7e11/cm2)
P(9.2e14/cm2) Rp = 1.09um
CONCENTRATION (atoms/cc)
DEPTH (microns)
10^20
10^19
10^18
10^17
10^16
10^15
0.0
0.5
1.0
1.5
2.0
2.5
3.0

FIG. 4D


WAFER 5: 1 MeV / 5e14 P. 1150 C ANNEAL-1
10^{20}
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
CONCENTRATION (atoms/cc)
48
O(1.8e12/cm2)
C(6.0e10/cm2)
P(4.8e14/cm2)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
DEPTH (microns)